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Hittman Associates, Inc, Columbia, Md

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A demonstration was conducted of a system for removing spilled hazardous materials from pond bottoms and separating the hazardous materials and suspended solids from the resulting dredged slurry. The removal system consisted of a MUD CAT dredge. The processing system consisted of a pair of elevated clarifier bins in series, a bank of hydrocyclones, a cartridge filter unit, and a Uni-flow bag-type fabric filter.

The MUD CAT proved efficient in removing particulate simulated hazardous materials from the pond bottom without imparting a substantial amount of turbidity to the water. The processing system was effective in removing particulate simulated hazardous materials from the processing stream and also in removing most of the pigment from a latex paint which was tested.

A conceptual portable system for processing at 1500 gpm was prepared. This system consisted of a scalping-classifying tank combined with spiral classifiers, Uni-Flow filter, and an inclined tube settler.

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REMOVAL AND SEPARATION OF SPILLED HAZARDOUS MATERIALS FROM IMPOUNDMENT BOTTOMS

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

A full-scale system has been evaluated for safely removing and processing hazardous materials from pond bottoms. A spilled hazardous material that has settled to the bottom of an impoundment poses immediate safety and health hazards to the public and to the environment and, further, continues to present a danger and to degrade the environment until it is removed and properly disposed of. Those concerned with the cleanup of spills and with environmental restoration, as well as public health and safety officials, will find useful information in this report. Further information may be obtained by contacting the Oil and Hazardous Materials Spills Branch of IERL-Ci at Edison, New Jersey 08817.

David G. Stephan
Director
Industrial Environmental Research Laboratory
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ABSTRACT

A demonstration was conducted of a system for removing spilled hazardous materials from pond bottoms and separating the hazardous materials and suspended solids from the resulting dredged slurry. The removal system consisted of a MUD CAT dredge, which can pump a discharge of approximately 1500 gallons per minute with a solids concentration of 10 to 30 percent. The processing system--in order of processing of material--consisted of a pair of elevated clarifier bins placed in series, a bank of six 4-inch diameter hydrocyclone cones, a conventional cartridge filter unit, and a newly developed Uni-Flow bag-type fabric filter.

Four different simulated hazardous materials were placed on the pond bottom, namely, very fine iron powder, fine glass beads, iron filings, and coal. These materials were then removed from the pond bottom by the MUD CAT dredge and pumped through the processing system. Tests were conducted to determine the efficiency of removal of these materials from the pond bottom by the dredge and also the efficiency of the processing system in removing these simulated hazardous materials from the dredged slurry. Using latex paint, a test was also conducted on the efficiency of the processing system in removing a real hazardous material from dredged slurry.

The MUD CAT dredge was very efficient in removing the simulated hazardous material from the pond bottom, averaging 99.3 percent removal for the four materials tested. Similarly, the overall processing system removed essentially all of the glass beads, iron filings, and coal, and 99.9 percent of the iron powder from the dredged slurry. During processing of the latex paint, 95.5 percent of the pigment was removed by the system.

After the field demonstration, evaluations and investigations were conducted on the tested apparatus, as well as on other equipment that could be used in a full 1500-gallons-per-minute portable processing system. A system consisting of a portable scalping-classifying tank combined with spiral classifiers, a Uni-Flow filter, and an inclined tube settler was conceptualized and preliminarily analyzed.

This report was submitted in fulfillment of EPA Contract Number 68-03-0304 by Hittman Associates, Inc. Work was completed as of October 31, 1974.

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The field demonstration of the dredging and processing of the simulated hazardous materials was done in cooperation with the Prince George's County, Maryland, Department of Public Works. They allowed unrestricted use of their sediment pond for dredging operations and the surrounding land for the processing.

SECTION I

INTRODUCTION

Practical methods for the removal and processing of hazardous or semihazardous materials from the bottoms of water bodies are receiving relatively high priority as targets for environmental action. Not only must the offending material be removed from the bottom sediments in an efficient and safe manner, but the removed sediment and hazardous material mixture must also be processed and disposed of in an environmentally acceptable and safe manner.

Consequently, Hittman Associates, Inc., under contract to the U.S. Environmental Protection Agency, conducted a demonstration of a system for the removal and processing of hazardous and semihazardous materials from the bottom of a shallow pond. Since it is difficult to justify the spilling of real hazardous materials into an aquatic environment even under research conditions, a number of simulated hazardous materials were spilled onto a pond bottom for the removal and processing demonstration. These simulated hazardous materials were relatively innocuous substances whose physical properties were chosen to represent a range of properties which might be displayed by real hazardous materials.

The purpose of the demonstration project was twofold. The first was to demonstrate a technique for removing hazardous materials from bottoms of water bodies at a high rate and yet have minimal adverse effects on the surrounding water body. The second purpose of the program was to evaluate a portable system which could be set up to process the sediment and hazardous materials mixture and return clean water to the pond.

The removal and processing systems used for this demonstration were the same as used on a previous EPA contract (Ref. 1) which demonstrated the dredging and processing of plain sediments. The removal system used was a MUD CAT dredge manufactured by National Car Rental System, Inc. It is specially designed for use on small bodies of water, and to impart minimum turbidity to the water while dredging. It can discharge approximately 1500 gallons per minute (gpm) of slurry with a solids concentration of 10 to 30 percent. Processing was performed by a system consisting of a pair of elevated settling bins, a bank of hydrocyclones, a standard cartridge-type water filter unit, and a bag-type filter known as a Uni-Flow filter. Basically, the Uni-Flow filter consists of a number of hanging hoses. Dirty water is pumped into the inside of the hoses and is allowed to filter through them. The suspended matter is trapped on the inside of the hoses. Periodically, the collected sludge is flushed from the inside of the hoses.

Each piece of equipment was evaluated as to its ability to remove the simulated hazardous materials along with the dredged solids. A conceptual design of a portable processing system was prepared based on the results of the field demonstration and additional manufacturer's literature.

This report constitutes the final report on the entire project. It includes the results of the field trials of the processing system, the evaluation of sediment processing equipment, and a conceptual design of a portable system for removing and processing hazardous materials from water bodies.

SECTION II

CONCLUSIONS

The MUD CAT dredge is an effective method for removing undesirable particulate materials from pond bottoms. However, it can be expected that up to one foot of bottom sediments will be removed along with the undesirable material, since it is difficult to regulate the depth of cut to less than a few inches.

The portable separation system which was field tested consisted of two elevated clarifier bins, hydrocyclones, a cartridge filter unit, and a Uni-Flow bag-type fabric filter. It proved efficient in removing particulate undesirable material along with the suspended solids present in a dredged slurry. Through a test on latex paint, there is also an indication that the system is applicable to removing some components of liquid hazardous materials present in dredged slurries.

Of the system elements downstream of the elevated bins, the hydrocyclones consistently removed the greatest amount of the particulate simulated hazardous material from the dredged slurry. The overall quality of the effluent from the processing system was adversely affected by leaks in the Uni-Flow hoses, which allowed unfiltered water to enter the effluent.

During the processing of latex paint, the hydrocyclones removed none of the pigment from the process stream. The Uni-Flow filter was the most effective component of the processing system in removing the paint pigment from the processing stream.

A portable hazardous materials removal and separation system similar to the conceptual system presented herein can be designed and assembled to operate at a throughput flow rate of 1500 gallons per minute. Such a system would require five semitrailer trucks to transport the entire system.

SECTION III

RECOMMENDATIONS

It is recommended that the MUD CAT dredge or its equivalent be utilized for the removal of particulate hazardous materials from water bodies when high flow rates and/or rapid removal is desired, since it produces a minimum resuspension of the dredged material into the surrounding water body.

Consideration should be given to the construction of a portable processing system similar to the conceptual system presented (consisting of a scapling-classifying tank combined with spiral classifiers, a Uni-Flow filter, and an inclined tube settler) if there is a continued projected need for a high-flow-rate hazardous materials processing system. Before finalization of design of such a system, field evaluations should be performed on the system components to ensure their working as projected at the full 1500-gallons-per-minute flow rate.

SECTION IV

FIELD DEMONSTRATION DESCRIPTION

REMOVAL SYSTEM

The system utilized for removing the spilled simulated hazardous materials from the pond bottom was an approximately 30-foot-long MUD CAT dredge manufactured by National Car Rental System, Inc., MUD CAT Division. The dredge moves in straight-line directions by winching itself along a taut, fixed cable. Bottom sediment removal equipment on the dredge consists of an eight-foot-long, horizontally-opposed, adjustable depth, power-driven auger and a pump rated at about 1500 gpm with a 10 to 30 percent solids concentration of the dredged slurry. A retractable mud shield over the auger minimizes mixing of the disturbed bottom deposits with the surrounding pond water. The dredge also comes equipped with a rock box into which objects greater than eight inches in diameter (the diameter of the discharge line) are automatically discarded before the dredged slurry is pumped into the discharge line. Photographs of the MUD CAT dredge are contained in Appendix A.

PROCESSING SYSTEM

The system used for processing the suspended sediment and simulated hazardous material dredged slurry was set-up on a 50-foot-high knoll, approximately 600 feet from the edge of the pond. It included, in order of processing of material:

1. Two steep-sided elevated bins, each with an initial capacity of 36 cubic yards, installed in series. They are of the type typically

used in concrete batch plant operations. The discharge from the dredge was pumped directly to the first bin where settling of suspended solids occurred. The slurry was then allowed to overflow into the second bin, where additional settling occurred. From the second bin, the flow was split to either a temporary holding/settling basin or the feed pump for the secondary separation phase. Each of the elevated bins provided about 144 square feet of surface area for settling.

2. A bank of hydrocyclones manufactured by DEMCO Incorporated, and consisting of six four-inch style H cones with three-gallon silt pots, a closed underflow header, and automatic solids unloading.

3. A commercially available cartridge-type water filter manufactured by Crall Products, Inc. The unit consisted of four model 16-17-51 filters, operating in parallel, with an automatic backflushing machanism. Each of the filters contained 51 permanent sand cartridges with filter openings rated at 25 microns.

4. One Uni-Flow bag-type fabric filter consisting of 720 one-inch diameter, 10-foot-long, woven polypropylene hoses. The hoses were arranged in six banks of 120 hoses each. This enabled the shutting-down of one bank for hose maintenance or replacement while the other five banks could be kept on-line. The slurry was pumped into a top header which distributed the influent to each bank of hoses. The filtrate from the hoses is collected in a bottom

tray and allowed to flow by gravity back to the pond. Normally, every 5-1/2 minutes the sludge within the hoses is drained for 30 seconds into a collection trough and allowed to flow by gravity into a sludge disposal basin.

Figure 1 is a schematic diagram of the overall processing and sludge disposal system. Photographs of the various components of the processing system are contained in Appendix A.

FIELD TESTS PERFORMED

Three separate types of tests were performed during the field demonstration:

1. Tests to determine the extent of resuspension of material into the water column during normal dredging and also during and after a simulated total failure of the MUD CAT prime mover pump or blockage of the discharge line. These conditions would cause the dredged slurry already in the discharge line to flow back into the pond.
2. Tests to determine the suitability of the MUD CAT and dredged slurry processing system for the removal and processing of hazardous materials from a small pond. Simulated hazardous materials were used during the tests for the reasons noted in Section III. The simulated hazardous materials used were very fine iron powder, fine glass beads, iron filings, and coal. Table 1 shows the physical characteristics of the simulated hazardous materials and the amounts placed on the pond bottom.

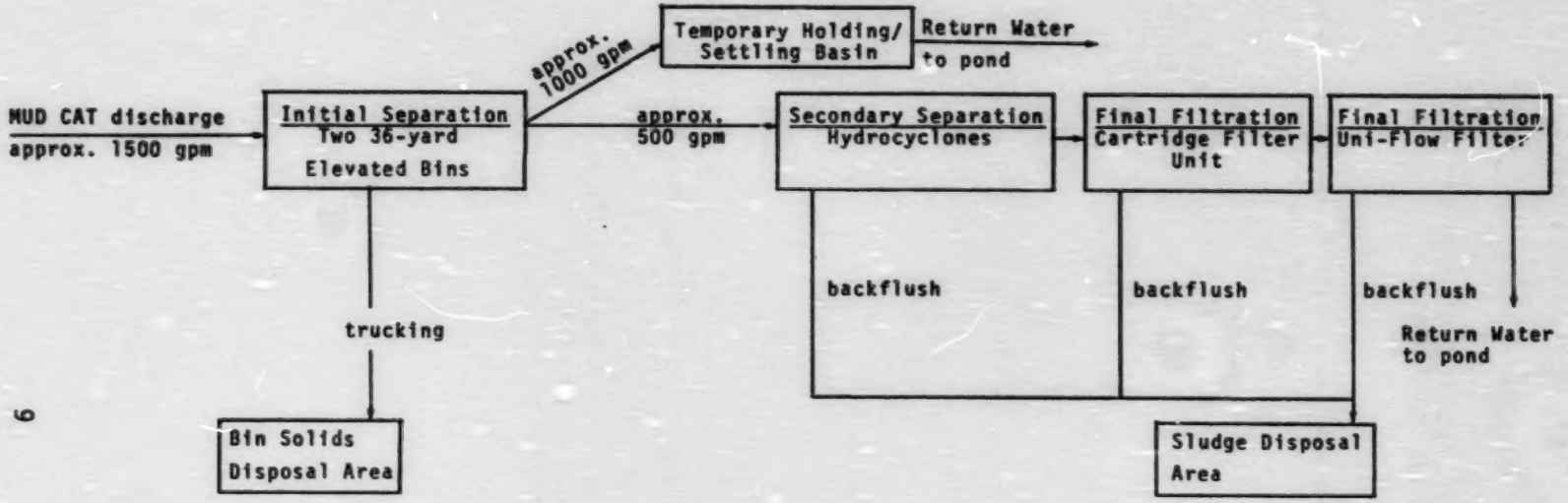


FIGURE 1. Schematic of Processing and Sludge Disposal System

Table 1. CHARACTERISTICS OF SIMULATED HAZARDOUS MATERIALS

Material	Amount (lb)	Particle size (microns)	% Finer
Iron powder (S.G.=5.04)	800	420	100.0
		250	99.9
		105	82.7
		75	64.7
Glass beads (S.G.=2.50)	500	250	100.0
		105	9.7
		75	1.5
Iron filings (S.G.=7.88)	500	2,000	100.0
		420	81.2
		250	42.2
		105	9.5
		75	5.1
Coal (S.G.=1.44)	500	3/4 in.	71.4
		4,760	8.1
		2,000	0.8
		420	0.5

Note: The "% Finer" column shows the percent of the material that has a particle size equal to or smaller than the size indicated in the adjacent "Particle size" column.

3. A brief test to determine the efficiency of the processing system in removing real hazardous material from a dredged slurry. In this test, a latex paint was dumped directly into the influent to the processing system and the amount of pigment removed by the processing system was determined.

FIELD TEST PROCEDURES

Simulation of Total Failure of the Dredge

The MUD CAT dredge was positioned in a location on the pond such that turbidity imparted to the pond by the simulated failure could disburse in an unimpeded manner to all areas of the pond. The MUD CAT was operated at normal pump rate (1500 gpm), rate of advance (10 feet per minute), and mud shield position (up) for three minutes to ensure that the discharge line was fully charged with dredged slurry that was representative of normal operating conditions. The MUD CAT operated in about four feet of water for the test.

After three minutes the MUD CAT's prime mover was shut off, simulating a total failure. The pump stopped, there was no movement along the central cable, the auger ladder was neither raised nor lowered, and the turbidity shield was not moved.

Water sampling and photographic documentation were done simultaneously. A two man sampling team worked from a work boat and sampled at less than five feet from the MUD CAT auger before dredging, at five and ten feet from the MUD CAT auger during dredging, at five feet and ten feet from the auger during the simulated failure, at four foot intervals (composite sample) from zero to twenty feet

from the auger immediately after the simulated failure, and a final sample at twenty feet from the auger after the simulated failure. Laboratory tests were performed to determine total suspended solids concentration for all samples collected. The photographers attempted to document any turbidity, discoloration, or plume imparted to the pond during the conducting of the simulated failure.

Removal and Processing of Simulated Hazardous Material from a Pond Bottom

A test area eight feet wide and 28 feet long, with lead-in and lead-out areas of four feet at each end, was prepared on the pond bottom such that the center line of the test area corresponded to the MUD CAT's positioning cable. Marker poles were placed at the corners of the test area, and the MUD CAT positioning cable over the test area was marked at four-foot intervals to provide reference points for bottom sampling. Each simulated hazardous material was placed on the bottom of the test area in a uniformly distributed pattern using a 6-foot length of 6-inch diameter P.V.C. pipe.

With the MUD CAT positioned well outside the test area, pond water only was pumped into the bins until they were full and the process system was balanced and backflushed. During this pumping, the process system was charged with clean pond water and all pressure controls were adjusted to proper balance. The auger of the MUD CAT was lowered to the pond bottom as it reached the lead-in area at a rate of ten feet per minute. After all dredge operations were stabilized during the traverse of the lead-in area, the test area was traversed in a smooth and continuous manner under normal operating parameters. Auger rotation was

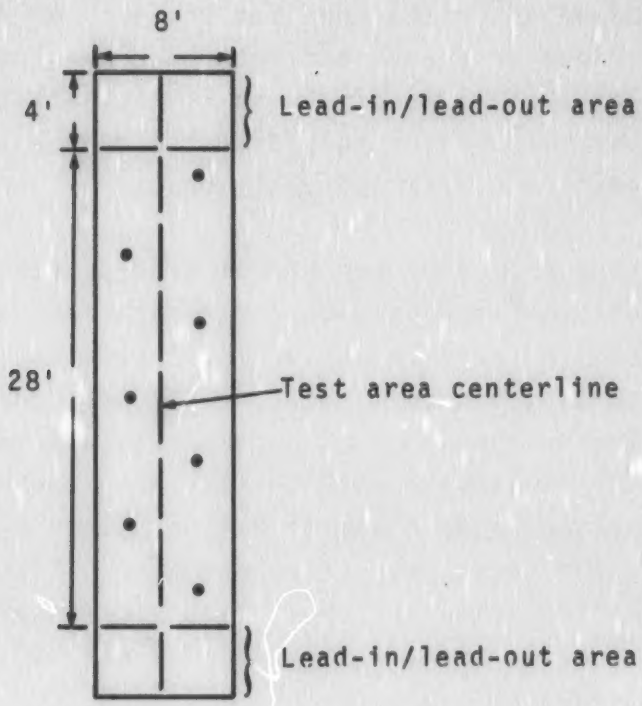
stopped after the complete traverse of the test area and lead-out area and pond water only was pumped in order to clear the dredge discharge line of all simulated hazardous material. During this time the dredge advanced to a position remote from the test area.

A survey of the pond bottom was conducted before and after each simulated hazardous material test to determine the amount of pond bottom material removed by the MUD CAT during each test. A La Motte Chemical Co. Code 1061 Bottom Sampling Dredge was used to collect samples of the bottom after each simulated hazardous material removal test. The bottom sampling pattern was on alternate, four-foot centers beginning two feet inside the test area. Figure 2 shows this sampling pattern. Thus, a total of seven bottom samples were collected after each simulated hazardous material removal test, except for the first test using fine iron powder, when each four-foot square area was sampled and a total of 14 samples were collected.

The process system was balanced and backflushed during the initial pumping of the pond water only. All process system components were operated without backflushing during the conduct of the test. The two minute test run time was less than the time between normal automatic backflushing cycles.

Effluent sampling was accomplished as follows:

(1) MUD CAT discharge: One composite sample, consisting of small, discrete samples collected at ten-second intervals, was collected over a two minute time period which began one minute after sediment was first observed in the discharge line.



• = normal bottom sampling locations

FIGURE 2. Plan View of Simulated Hazardous Materials Test Area and Sampling Points on Pond Bottom

(2) Elevated bin discharge: The procedure for sampling was the same as for the MUD CAT discharge except that sampling was started at one and one-half minutes after the start of sample collection at the MUD CAT discharge.

(3) Hydrocyclone unit: Same as bin discharge.

(4) Cartridge filter: Same as bin discharge.

(5) Uni-Flow filter: Procedure was the same as the preceding except that the first sample was taken thirty seconds after collection of the first sample from the cartridge filter unit, that is, two minutes after the start of sampling at the MUD CAT discharge.

After the test, sludge sampling was accomplished as follows:

(1) Elevated bins: All water was decanted from the bins. Core samples were taken at several locations across the sediment, and one composite sample was prepared for each bin.

(2) Hydrocyclone unit: One sample of material ejected from the sludge pots just at the start of backflushing was obtained.

(3) Cartridge filter unit: One composite sample of all four filters' backflush material was collected.

(4) Uni-Flow: One sample of material ejected from the sludge collecting chambers just at the start of backflushing was obtained.

Laboratory tests were performed to determine total suspended and dissolved solids for all samples collected.

Processing of Latex Paint

The MUD CAT was operated at normal conditions for providing dredged slurry to the process system except that the pumping rate was reduced to 500 gallons per minute. To ensure that no hazardous material was introduced into the temporary holding basin, the overflow from the second bin was blocked and all flow was diverted through the processing system. After the bins were full, the processing system was balanced as dredged slurry was pumped through it. Backflushing was performed manually on all system components to clear them. Hazardous material (latex paint) was then introduced directly into the first bin into the dredge discharge plume at a uniform rate. No backflushing was performed during the processing of hazardous material; the time for the test was less than the time for a normal backflushing cycle.

Sampling of effluent and sludge was the same as for the tests using simulated hazardous materials. Laboratory tests were performed to determine total suspended solids, and dissolved and adsorbed pigment for all samples collected.

LABORATORY ANALYSES

Analysis for the amount of suspended solids in the pond water during the simulated dredge pump failure test and in the effluents of the elements of the processing system was performed in accordance with Standard Methods for the Examination of Water and Wastewater(Ref. 2).

The concentrations of simulated hazardous material in the effluents of the system elements and remaining on the pond bottom after dredging were determined by three methods:

(1) Iron Powder and Iron Filings: These materials were separated from soil particles magnetically. Two grams of thoroughly blended dry sample were placed in a petri dish and covered with a glass cover. A seven and one-half pound horseshoe magnet was placed on the covered petri dish. The petri dish was then agitated. The iron particles were trapped on the inside of the glass cover during the agitation. The glass cover and magnet were removed carefully so that iron particles remained trapped on the inside of the glass cover. The iron particles were removed and the separation process was continued until no iron particles were found trapped on the inside of the glass cover. The petri dish and soil was then weighed. The difference between the weight of the petri dish and two gram soil sample before the removal of iron particles and the weight of the petri dish and soil after the removal of iron particles was taken as the weight of iron particles for a two gram sample. From this result, the percent of iron powder or iron filings by weight in the sample was calculated.

(2) Coal: It was possible to separate the coal particles from the dry soil sample from the MUD CAT effluent by hand. The weight of coal compared to the total weight of the dry sample yielded the percent of coal, by weight, in the sample. For the remaining effluents of the processing system, a different approach was used. The coal from the MUD CAT discharge sample was pulverized. It was then blended back into the dry material in the sample. A

small sample of this blend was removed and placed in a glass petri dish for microscopic examination. This MUD CAT discharge sample was then used as the test sample. By comparing the known amount of pulverized coal in this test sample to the amounts found upon microscopic examination of samples of the other effluents, the percent of coal in the samples was estimated. For example, since the amount of coal in the test sample was 4.2 percent by weight, a sample which exhibited one-fourth as much coal upon microscopic examination was determined to have approximately a 1.0 percent concentration of coal.

(3) Glass beads: Microscopic examination was also employed in the determination of the concentrations of glass beads in the system effluent samples. A grid of 144 squares was affixed to the glass petri dish. A small portion of glass beads was placed in the petri dish and weighed. Using the 144 square grid as a reference, the total number of glass beads was counted under microscopic observation by summing the number of beads observed and counted in each square. This process was repeated several times, and an average weight per glass bead was obtained. This value was applied to the number of glass beads subsequently observed and counted in measured portions of the effluent samples. From this, the concentrations of glass beads in each sample was determined.

The hazardous material tested, latex paint, was analyzed by analyzing the concentrations of calcium carbonate ($CaCO_3$)

both in solution and adsorbed to the sand and silt particles in each sample. Calcium carbonate is one of the major constituents of the pigment. The percentage of calcium carbonate in the pigment was given in the analysis of the paint on the paint containers. Using the percentage of calcium carbonate in the pigment, the amount of calcium carbonate occuring naturally in the pond waters, and the percentage of calcium carbonate in the samples collected, the amount of pigment in the effluent of each element was determined.

SECTION V

RESULTS

SIMULATED DREDGE PUMP FAILURE

The results of the simulated dredge pump failure test are shown in Table 2. During normal dredging, the plume of suspended material imparted to the pond was observed to be confined to within 15 to 20 feet from the dredge. At 20 feet from the auger of the dredge, the concentration of suspended solids in the pond water fell to within the range normally present in the pond.

During the simulated failure, the plume of suspended material imparted to the pond was observed to stay within about 25 feet from the dredge. Concentrations of suspended solids within this 25-foot radius were, in some places, over ten times the concentrations found during normal dredging. Even though more suspended solids were imparted to the pond during the simulated failure test than during normal dredging they were observed to be confined to within the approximate same distance from the dredge as during normal dredging.

Immediately after backflow from the simulated failure test ended, the concentration of suspended solids fell off rapidly with distance from the dredge auger. Within a few minutes, the turbidity was observed to approach that normally present in the pond.

REMOVAL OF SIMULATED HAZARDOUS MATERIALS FROM POND BOTTOM

Throughout these tests, the primary objective was to remove as much of the simulated hazardous material from the pond

Table 2. RESULTS OF SIMULATED DREDGE PUMP FAILURE TEST

Condition	Distance from MUD CAT Auger (ft)	Depth from Surface (ft)	Suspended Solids Concentration (mg/l)
Before Dredging (normal pond)	5	1	39
	5	3	50
	5	5	64
	5	7	523
During Normal Dredging	5	1	88
	5	5	179
	10	1	54
	10	5	86
	20	1	39
During Simulated Failure	5	1	900
	5	5	1260
	10	1	648
	10	5	175
After Simulated Failure (backflow complete)	20 composite: 0 to 20 ft	1	89
		1	226

bottom as possible while operating at the normal pumping and advance rates for the MUD CAT dredge. A secondary consideration was to remove as little as possible of the sediments from the pond bottom while picking up the simulated hazardous material. One pass over the test area by the dredge was usually sufficient to remove essentially all of the simulated hazardous materials, except during the glass beads test, when two passes were made over the test area. Table 3 presents the results of the removal of the simulated hazardous materials from the pond bottom. The variability in the thickness of sediment removed for the different tests reflects the inability of the dredge operators to determine precisely the depth to the pond bottom in the very soft sediments present in the test area.

A statistical analysis was performed on the results obtained from the bottom sampling tests after each simulated hazardous material removal test. This analysis gives an indication of the degree of reliability of the bottom sampling results. Table 4 is a summary of the statistical tests. It indicates that the number of bottom samples taken after each test was adequate to predict the efficiency of removal of the simulated hazardous materials by the MUD CAT dredge within an acceptable range of error. In all cases, the total error interval in the number of pounds predicted left on the bottom of the pond through the sampling program is less than one percent of the total weight of material placed on the bottom.

During the dredging of the coal it was observed that very fine particles of coal became suspended in the surrounding pond water. This was probably due to the action of the auger on the MUD CAT dredge causing the breaking up of the

Table 3. REMOVAL OF SIMULATED HAZARDOUS MATERIALS FROM POND BOTTOM

Material	Amount Placed on Bottom (lb)	Amount Remaining on Bottom (lb)	% Removed	Average Thickness of Sediment Removed (ft)	No. of Passes by Dredge
Iron Powder	800	8.0	99.0	1.12	1 (forward)
Glass Beads	500	<0.1	99.9+	0.61	2 (forward & backward)
Iron Filings	500	0.4	99.9	0.22	1 (backward)
Coal	500	2.1	99.6	1.14	1 (backward)

Table 4. CONFIDENCE LEVELS OF BOTTOM SAMPLING TESTS

Test Material	Number of Samples	Predicted Amount Removed (lb)	Total Sampling Error over Entire Test Area (lb)	Confidence Level
Iron Powder	14	792.0	± 6.0	90
Coal	7	>499.9	± 1.5	90
Glass Beads	7	499.6	± 1.0	99.9
Iron Filings	7	497.9	± 1.0	99.9

larger lumps of coal into smaller particles and the subsequent suspension of these particles in the pond water. These very fine particles remained in suspension for a long time and settled back to the bottom, both within and outside the test area, within about one day after the test was complete. Although the total weight of the suspended coal was very small, it did give a black color to the pond sediments up to a distance of approximately 20 feet from the edge of the test area. No similar problems were observed with the other simulated hazardous materials tested.

REMOVAL OF SIMULATED HAZARDOUS MATERIALS BY PROCESSING SYSTEM

Table 5 summarizes the composite dredged slurry concentrations at each sampling point in the processing system for the four simulated hazardous materials tested. It gives an indication of the efficiency of removal of suspended solids for the various units in the processing system. As can be seen from Table 5, the dredge discharged between 10 and 14 percent solids during the tests, which is within the normal range. Processing system flow ranged between 100 and 300 gpm and was restricted mainly by backpressure from the cartridge filter unit and restriction of the flow through the Uni-Flow filter hoses by the trapped sediment.

The amount of simulated hazardous material entering/leaving each system component was also determined so that each component of the system could be evaluated as to its ability to remove the various test materials along with the normal suspended solids. The main interest was in the processing system units downstream from the elevated bins. Table 6 is a summary of the removal efficiencies of the hydrocylcones, cartridge filter unit, and Uni-Flow filter. Here, the three

Table 5. COMPOSITE DREDGED SLURRY CONCENTRATIONS

Sampling Point*	Total Suspended Solids Concentration (mg/l) - Test			
	Iron Powder	Glass Beads	Iron Filings	Coal
#1	129,210	107,560	107,030	138,020
#2	61,320	87,560	67,390	55,830
#3	40,390	31,400	44,690	49,480
#4	26,200	22,740	26,250	34,680
#5	230	570	660	520
System Flow (gpm)	100	100	300	250

*Sampling Point Key:

#1 = MUD CAT discharge into elevated bins
#2 = Bin effluent - Influent to hydrocyclones
#3 = Hydrocyclone effluent - Influent to cartridge filter unit
#4 = Cartridge filter effluent - Influent to Uni-Flow filter
#5 = Uni-Flow effluent (return water to pond)

types of removal equipment can be compared on a step-by-step basis in terms of their ability to remove the simulated hazardous materials which remained in the dredged slurry after passing through the clarifier bins.

Table 6. SUMMARY OF SYSTEM COMPONENT REMOVAL OF SIMULATED HAZARDOUS MATERIAL

	Percent removal of simulated hazardous materials reaching the processing system after the elevated bins			
Component	Iron powder	Glass beads	Iron filings	Coal
Hydrocyclones	42.9	87.8	83.8	55.2
Cartridge filters	22.0	6.1	7.5	29.9
Uni-Flow	35.0	6.1	8.7	14.9
Return water to pond	0.1			
	100.0	100.0	100.0	100.0

The overall consideration of this program was to briefly test the ability of the processing system, which was already set up to remove suspended solids from dredged material, to also remove certain types of hazardous materials along with the suspended solids. Time and budgetary constraints were such that it was impossible to accurately establish the fate of all the dredged materials which were trapped in or passed through the elevated settling bins. The removal of hazardous materials by the closed portion of the processing system, as given in Table 6, could be measured quite easily to a high degree of accuracy. However, results from the total processing system analyses were accurate enough to compute materials balances for the entire removal and processing system, including the elevated bins,

for two of the four simulated hazardous materials tests. Materials balances based on a 100 gpm flow rate are shown in Table 7. Materials balances shown in Table 7 for the iron powder and coal are estimated values based on observations of the influent and effluent concentrations. Appendix B contains additional data collected and calculations performed during this study.

REMOVAL OF LATEX PAINT BY PROCESSING SYSTEM

Testing the ability of the processing system to remove a real hazardous material, in this case latex paint, was done after dredging of the simulated hazardous materials was complete. Twenty-one gallons of paint were dumped directly into the dredge discharge plume into the first elevated bin. The paint was dumped within a two-minute period as dredging of normal bottom sediments was occurring at a reduced rate of 500 gpm. Samples were collected throughout the processing system during the dumping of the paint for an additional two minutes afterward. Table 8 presents the results of this processing of latex paint.

Table 7. SIMULATED HAZARDOUS MATERIALS BALANCE

Unit	Test Material (lb removed per 100 gpm)			
	Glass Beads	Iron Filings	Iron Powder*	Coal*
Elevated bins	6.2	28.9	7.4**	5.3**
Bypass	19.7	2.7	4.9**	2.7**
Hydrocyclones	17.3	2.2	2.1	1.5
Cartridge filters	1.2	0.2	1.1	0.8
Uni-Flow	1.2	0.2	1.7	0.4

* Because of inaccuracies in measuring the amount of iron powder and coal in the bypass, and the fact that these two simulated hazardous materials were nonuniformly distributed in the bin sediments, the values shown for the pounds removed by the elevated bins and bypass may not reflect the true values.

** Imputed value.

Table 8. RESULTS OF PROCESSING LATEX PAINT

System Unit	Effluent Suspended Solids Concentration (mg/l)	Absorbed Pigment Removed (lb)	Pigment in Solution Removed (lb)	Total Pigment Removed (lb)
Hydrocyclones	140,500	0.00	-0.03*	-0.03*
Cartridge filters	103,040	4.02	0.00	4.02
Uni-Flow	94,430	5.83	0.03	5.86
Return water to pond	1,770	0.47	0.00	0.47

* The negative sign indicates that, in the hydrocyclones, the net effect was an increase in the pigment in solution. The source of pigment was that pigment adsorbed to silt particles which was agitated into solution by the action of the hydrocyclones.

SECTION VI

DISCUSSION OF FIELD RESULTS

REMOVAL SYSTEM

It is evident that the MUD CAT dredge is a relatively effective method for removing undesirable particulate materials from pond bottoms. It removed from 99 to over 99.9 percent of the material placed on the bottom within the test area. During some of the tests, however, up to approximately one foot of bottom sediments were removed along with the simulated hazardous material. Even though relatively brief tests were performed, the degree to which the test materials were removed by the dredge was observed to be influenced by two factors.

First is the fact that during a backward cut, the MUD CAT dredge has a greater efficiency for removal of sediment, and consequently, of spilled hazardous material, than during a forward cut. This is due to the fact that during a backward cut the mud shield is fully extended over the cutting auger and helps to prevent the resuspension of any bottom sediments into the surrounding water. This influence was first observed during the test for removal of glass beads. As the dredge traversed the area in a forward cut, the pond bottom was quickly sampled behind the dredge. The samples revealed that a large amount of glass beads had been left on the bottom. Therefore, the dredge traversed the area again, but in a backward cutting mode. The remaining tests were both performed using backward cuts by the dredge and showed higher removals than the first test when a forward cut was used (see Table 3). Secondly, the specific gravity, and possibly, the relative softness

of the material being picked-up was observed to influence the removal efficiency. During the two tests which were made with the same direction of cut, i.e., backward only, the lighter and softer material (coal) was observed to have a lower removal rate and also be dispersed into the surrounding water body more easily than the heavier and harder iron filings.

Overall, the MUD CAT performed very satisfactorily in removing undesirable particulate matter which had a wide range of specific gravities and particle size from a pond bottom. It is probable, therefore, that such a removal system would be satisfactory for the removal of most particulate hazardous materials spills which have settled to the bottom of a water body. The bottom sediments would have to be relatively soft to ensure a high percentage of pick-up by the MUD CAT dredge. The minimum depth of cut by the dredge into the pond bottom which produced efficient removal of the test material was approximately 0.3 feet.

It has been postulated that the MUD CAT dredge could be used somewhat as a floating pump platform to remove lighter hazardous materials because the MUD CAT intake can be elevated to the water surface. However, this is a relatively inefficient means of removing floating or suspended hazardous materials from a water body since large volumes of water would also be pumped and have to be processed. However, the MUD CAT might be used to divert small streams around a spill site.

PROCESSING SYSTEM

The ability of the processing system to remove a variety of undesirable particulate material along with suspended solids from a dredged slurry and return a relatively high quality

water to a pond was documented during the field demonstration. Essentially all of the glass beads, iron filings, and coal, and 99.9 percent of the fine iron powder were removed from the dredged slurry before the water was returned to the pond.

Through the test on latex paint, there was also an indication that the system is applicable to removing some components of liquid hazardous materials present in dredged slurry. During this test, 95.5 percent of the pigment reaching the system downstream of the clarifier bins was removed along with the suspended solids. Leakage of the Uni-Flow hoses prevented a greater removal efficiency, as evidenced by the high suspended solids concentration shown in Table 8.

The overall quality of the effluent from the processing system was adversely affected by leaks in the Uni-Flow hoses, which allowed unfiltered water to enter the effluent. This problem was also observed during previous field tests of the system on dredged slurry (Ref. 1). During the present tests, leakage was especially bad during the testing of latex paint, when an overall effluent suspended solids concentration of 1770 mg/l was measured. When hose failure is not a problem, the overall suspended solids concentration in the effluent can reasonably be expected to be in the range of 100 to 300 mg/l (Ref. 1).

Originally, the processing system was designed to be operated at a flow rate of 500 gpm. However, two conditions were found to prevent operation at this optimum processing rate. First, the backpressure in the cartridge filters, at flow rates approaching 400 gpm and at the dredged slurry

solids concentrations encountered, caused a reduction in flow rate. Secondly, sediment rapidly builds up in the Uni-Flow hoses. This buildup contributes to the back-pressure in the system. Flow rates must be adjusted downward to compensate for the increase in pressure on the hoses in order to prevent their bursting. Expedient flow rates for the Uni-Flow filter were found to be between 100 and 300 gallons per minute after the hoses had been coated by sediment.

The elements in the processing system downstream of the elevated bins operate as a closed system, the processing rate of which is dependent upon the operating characteristics of the most sensitive element. The Uni-Flow filter is the most sensitive to pressure and therefore is the element in the processing system upon which the total system is dependent.

The hydrocyclone unit has a specified operating pressure range in which removal of suspended solids is optimized. This pressure range corresponds to a system flow rate of between 420 and 540 gpm. Therefore, the maximum flow rate of approximately 300 gpm for the Uni-Flow filter after the hoses become blocked with sediment limits the efficiency of the hydrocyclone unit to a suboptimal range.

Efficiency of removal of the cartridge filters is not significantly affected by changes in flow rate or pressure. However, the cartridge filters can become the limiting element in the processing system if the filter cartridges become restricted by accumulated solids. When this happens the cartridge filter unit governs the processing rate of the system.

During the processing of the simulated hazardous materials, the hydrocyclones consistently removed the greatest amount of simulated hazardous material which entered the processing system after the bins. In three out of four tests, the Uni-Flow filter removed greater amounts of simulated hazardous material than the cartridge filter unit, even though it was downstream of the cartridge filters. After the test program was complete, the cartridge filters were opened and cracks were discovered in a number of the cartridges. These cracks were postulated to have occurred during backflushing of the filters and would allow unfiltered dredged slurry to leak through this unit.

Very little pigment in the water base paint processed as a hazardous material was found in solution in any of the system effluents; practically all the pigment in the effluent samples was adsorbed to silt particles. In the processing of the water base paint, the hydrocyclones removed no pigment. In fact, the hydrocyclone unit resuspended some pigment that had entered it adsorbed to silt particles, so that the unit made a negative contribution to the removal system. The cartridge filter unit removed no pigment from solution and removed less adsorbed pigment than did the Uni-Flow filter. The Uni-Flow filter was the only element in the system which removed pigment from solution.

The complete sediment processing system may not be applicable in all situations. Some components of the system are more suited for removing certain particle size ranges and specific gravities, and thus in some instances some of the components could possibly be eliminated. For example, as evidenced by the results, the hydrocyclones are most efficient in removing sand size or larger particles of

relatively high specific gravity. If the undesirable material is composed mainly of fines, little advantage will be gained by processing the material through hydrocyclones. This was especially evident during the latex paint test.

A degree of redundancy is provided in the system by utilizing both the cartridge filter unit and the Uni-Flow filter in the final filtration step. Both of these filters are not required for final filtration. From these tests with simulated hazardous materials and previous experiments with dredged slurries, the Uni-Flow filter proved to be more useful in the processing system than the cartridge filter unit: it can efficiently remove a variety of material with different particle sizes and specific gravities.

Sizing and selection of the individual components of the processing system should ideally be performed on a case-by-case basis. The clarifier bins, hydrocyclones, and Uni-Flow filter are all applicable to the processing of undesirable particulate material along with dredged sediments. Utilization of the cartridge water filter is limited in this application because of operational difficulties encountered while using it on slurries with high suspended solids contents, even though it did produce some removal of the simulated hazardous materials and the latex paint tested.

SECTION VII

CONCEPTUAL PORTABLE SYSTEM

GENERAL CONSIDERATIONS

The experience gained during the field demonstration was utilized to develop a concept for a system which could be utilized to remove and process hazardous materials spills which had settled to the bottoms of water bodies. The basic criteria which were followed in defining this system were:

1. The system had to be portable, preferably to fit and be transported on one or more semi-trailers.
2. The system had to have the capability to be easily and rapidly set up and disassembled.
3. The components of the system had to be reliable with the minimum possible chance of breakdown or breakage during processing.
4. Maintenance should be simple and preferably be performed while the system was on line with a minimum of hazard to personnel.
5. Capability should be present to process a wide range of anticipated hazardous materials.
6. Capital and operating costs should be reasonable.
7. The system had to have the capability of processing the full 1500 gpm flow from the MUD CAT at the expected solids loadings rates.

CONCEPTUAL SYSTEM DESCRIPTION

Overall System

After the data from the field demonstration were analyzed, additional data were reviewed for possible application to a portable hazardous materials processing system. These data consisted of manufacturer's literature, published reports, discussions with equipment manufacturer's representatives, and previous experience with and analysis of equipment which might be applicable for use in the processing system. The requirements of the system were balanced with the available state-of-the-art equipment and possible modifications or refinements to the equipment which were deemed feasible. Brief descriptions of alternative pieces of equipment which were considered for use in the separation system but not utilized are contained in Appendix C. Figure 3 is a schematic of the overall conceptual system for the removal and processing of hazardous materials from pond bottoms. It has been assumed that the MUD CAT dredge will be utilized for the removal operation. The dredge proved efficient in removing materials from a pond bottom as well as providing a minimum of contamination to the surrounding water, even under simulated failure conditions.

Initial Separation

From the results of the field demonstration and the subsequent review of additional data, it was apparent that initial separation of dredged solids and hazardous materials could best be accomplished by some form of settling basin. The elevated bins used in the field demonstration were judged to be too cumbersome in terms of erection and solids unloading, so that an alternative settling device was used in the conceptual system.

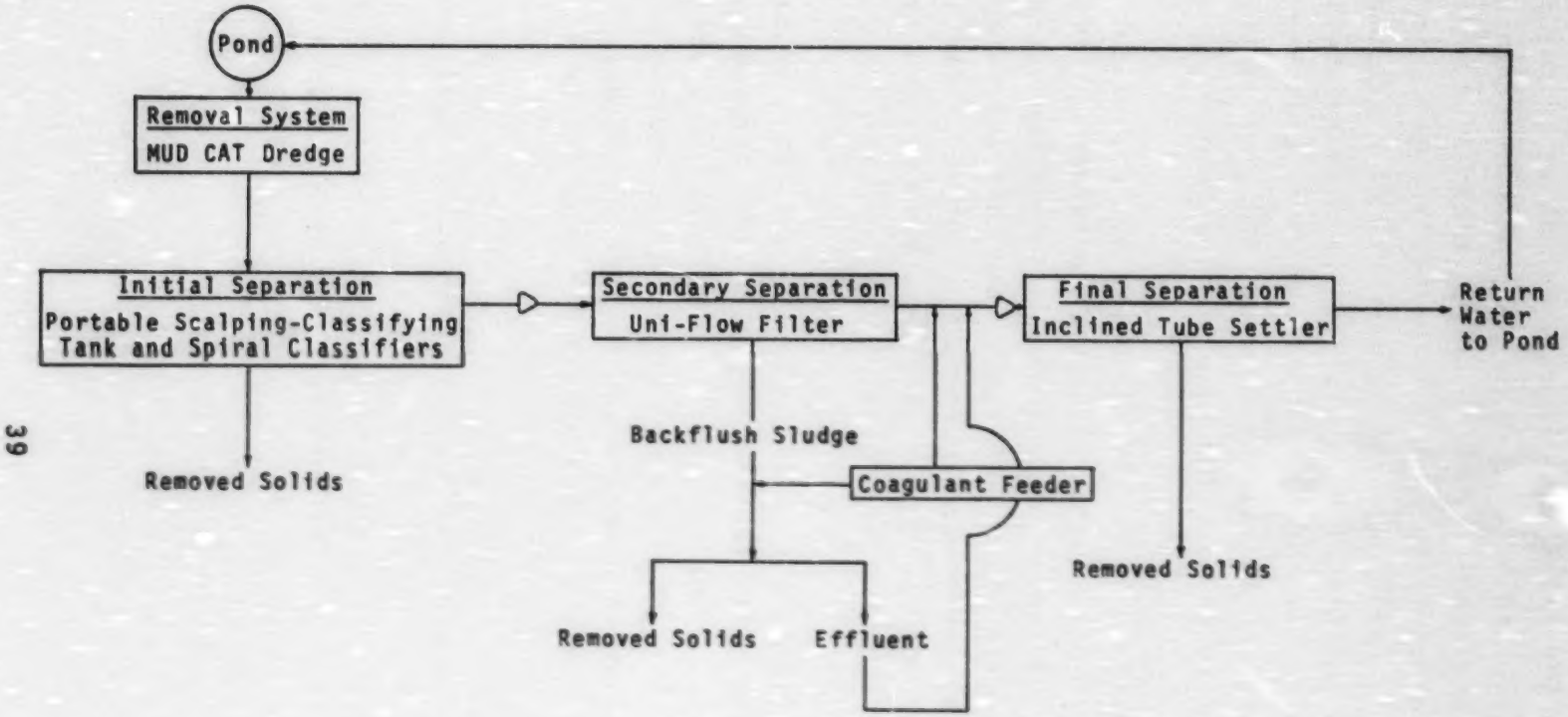


FIGURE 3. Schematic of Conceptual System

The equipment for the initial separation phase of the conceptual system consists of a portable hydraulic scalping-classifying tank combined with a spiral classifier. Basically, the scalping-classifying tank is a metal tank which is used in the sand and gravel processing industry to hydraulically separate sand and gravel from slurries, and to automatically meter the release of solids to collecting and blending flumes. The surface area of the tank determines the size particles that will be removed as a function of flow rate.

Scalping-classifying tanks have V-shaped bottoms to collect the settled solids and are equipped with valves on their bottoms which discharge the solids. Motor-driven vanes sense the level of solids in the bottom of the tank and automatically open the valves as the solids accumulate. The solids discharged through the valves drop into flumes which transfer the solids to spiral classifiers.

Spiral classifiers, also called screw classifiers or sand screws, are basically rectangular tanks with parallel sides, a vertical wall at one end, and a sloping bottom which extends to a height above the top of the other end wall. A rotating screw which operates on the incline conveys the settled solids up the sloped bottom and deposits them outside the tank.

Figure 4 shows a portable scalping-classifying tank combined with spiral classifiers. For the hazardous materials processing system, the tank would have a water surface of 40 ft x 10 ft. Two spiral classifiers supplied with the unit each have a screw diameter of 44 in. and a length of 32 ft.

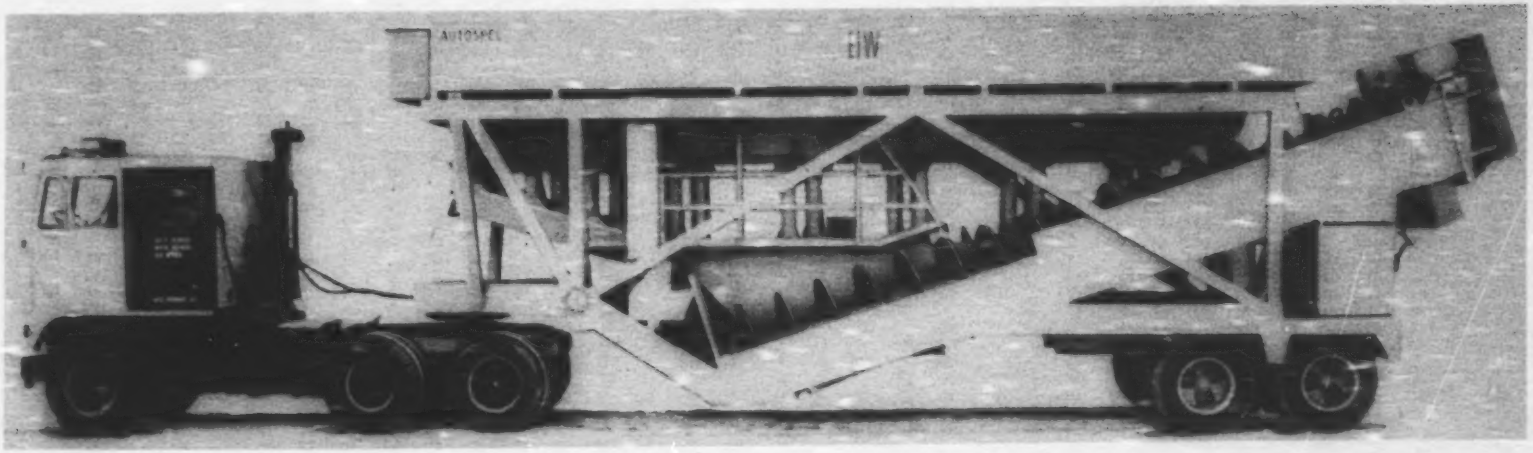


FIGURE 4. Portable Scalping-Classifying Tank Combined With Spiral Classifiers

Secondary Separation

The overflow from the scalping-classifying tank will go to the secondary separation portion of the system where the fine-grained materials (less than 74 microns in diameter) will be removed. In the conceptual system, hydrocyclones or cartridge filters will not be used. Hydrocyclones are most effective for removing sand size (74 micron) particles or larger. Because of operational and maintenance problems encountered with the cartridge filter unit during the processing of dredged slurries, this equipment was also deleted from the conceptual system.

The most promising piece of equipment for removing fine-grained material from a dredged slurry and returning a high quality water to the pond still appears to be some type of Uni-Flow filter. Experiments with five-inch diameter hoses (Ref. 1) showed that they would be better than one-inch hoses for this application. Mainly, fewer problems with hose blockage were encountered with the larger diameter hoses.

The hoses will be constructed of a polypropylene fabric and have wire cages on both the inside and outside of the hoses. The wire cages on the inside of the hose prevent the collapse of the hose during the draining cycle, thus producing a more effective cleaning of the hose. Wire cages on the outside of the hoses prevent excessive bowing of the hoses during operation of the filter. This enables the Uni-Flow filter to be operated at a higher pressure and thus a higher flow rate. The influent would enter through the bottom of the hoses.

Drained solids would fall into a collection trough beneath the unit. Coagulants will be added to the backflush sludge from the Uni-Flow filter and the effluent from this process will be recycled back into the system for final solids removal.

Final Separation

An inclined tube settler will be used as a final solids separation step in the portable system. This unit was included in the system to ensure that water of the highest quality is returned to the pond. Typically, the Uni-Flow filter has an effluent which averages a few hundred mg/l of suspended solids. An inclined tube settler would be ideal as a downstream addition after the Uni-Flow filter since settlers are used to clarify wastewater which usually have less than 1500 mg/l of suspended solids. The settler would also serve as insurance should a Uni-Flow hose burst and release the trapped hazardous materials into the effluent before the hose can be turned off.

Inclined tube settlers are basically composed of a bank of inclined tubes which may be circular, hexagonal, square, rectangular, or chevron-shaped in cross section. Wastewater influents flowing up through the tubes tend to drop their suspended solids loads due to the force of gravity on the suspended particles. The steep inclination of the tubes causes the settled sludge to counterflow along the side of the tubes after it accumulates. It then falls into a sediment storage sump below the tube assembly.

In the conceptual system a coagulant will be added to the influent to the inclined tube settler. Systems employing coagulation in conjunction with an inclined tube settler can remove particles six microns in diameter or smaller. Typical flow rates through inclined tube settlers are on the order of three to five gpm per square foot of tube cross section.

EQUIPMENT SIZE

Exact sizing of the conceptual portable system would depend upon the grain size distribution of the suspended solids which are present in the dredged slurry. In order to arrive at an approximate equipment size, an influent grain size distribution as shown in Figure 5 was assumed. This grain size distribution might be typical of many bottom sediments of rivers and ponds and was chosen to test the removal system's efficiency in removing the more critical finer particles. Fifty percent of the solids in the distribution are finer than sand size. Following are the parameters used in sizing of the equipment for the conceptual system:

System inflow:	1500 gpm
Grain size distribution of solids:	Figure 5
Specific gravity of solids:	2.60
Inflow suspended solids concentration:	20%

Initial Separation

A portable scalping-classifying tank combined with spiral classifiers which can handle a 1500 gpm flow rate is available as an off-the-shelf item (Ref. 3). Such a tank has a water surface area of 400 square feet and is capable of removing particles down to about 54 microns in size at a 1500 gpm flow rate. This means that 63 percent of the solids in the incoming dredged slurry will be removed in the initial separation phase. The tanks and spiral classifiers should be able to attain an underflow solids concentration of 50 percent. Table 9 shows the mass balance of the initial separation phase.

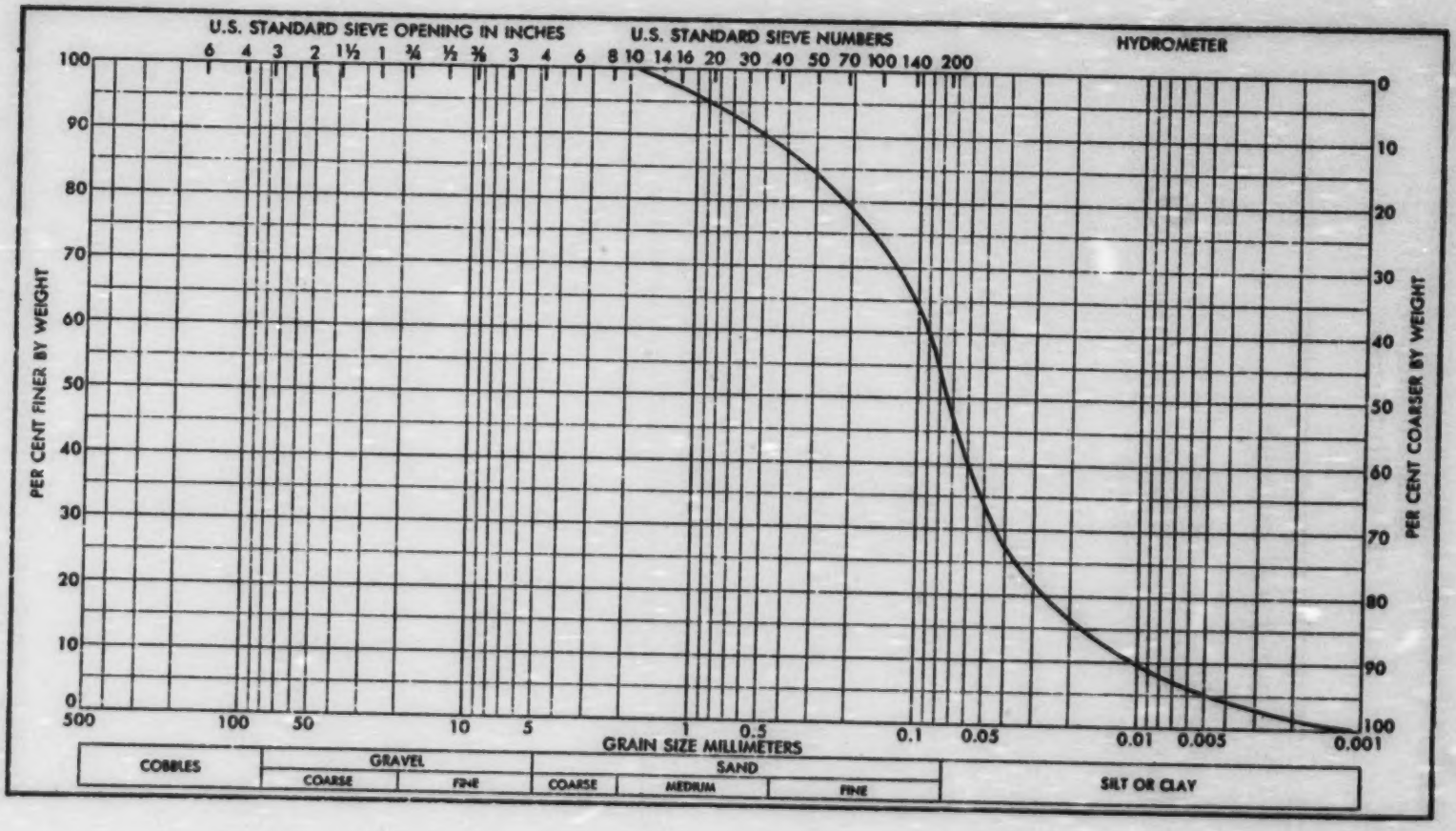

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ ⅜ 3 4 6 8 10 14 16 20 30 40 50 70 100 140 200
PER CENT FINER BY WEIGHT
PER CENT COARSER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY

FIGURE 5. Hypothetical Grain Size Distribution of Dredged Sediment

Table 9. MASS BALANCE OF INITIAL SEPARATION PHASE

Inflow (1500 gpm @ 20% solids)		
Solids:	2,850	lb/min.
Water :	11,400	lb/min.
Total Slurry:	14,250	lb/min.
Underflow (50% solids)		
Solids:	1,796	lb/min.
Water :	1,796	lb/min.
Total Slurry:	3,592	lb/min.
Overflow (1207 gpm @ 9.9% solids)		
Solids:	1,054	lb/min.
Water :	9,604	lb/min.
Total Slurry:	10,658	lb/min.

Secondary Separation

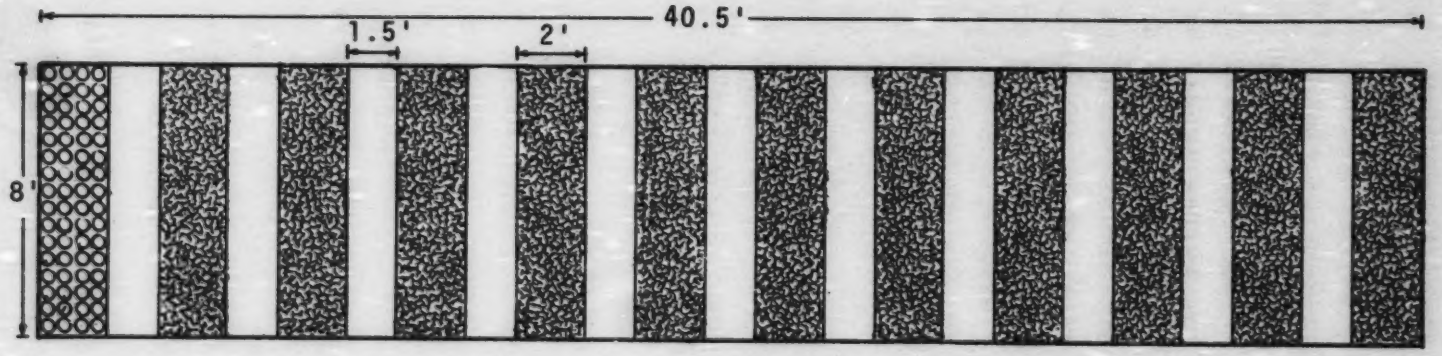
The Uni-Flow filter used for secondary separation will consist of 10-foot-long, 5-inch diameter hoses with wire cages on the inside and outside. Using these hoses at the solids loadings expected, the Uni-Flow filter should be able to process the slurry at an average rate of 0.13 gpm per square foot. This would require a minimum of 715 hoses to process the expected 1207 gpm expected to enter the secondary separation phase. Figure 6 shows a plan view of how these hoses would be arranged for the Uni-Flow filter in the conceptual system.

A coagulant will be added to the sludge which is drained from the Uni-Flow hoses. The solids settled from the sludge would then be disposed of and the supernatant would be recycled to be treated in the final separation phase.

Final Separation

The final separation phase, in the form of an inclined tube settler, is included as added insurance for a clean system effluent. Coagulant will be added to the influent to the inclined tube settler in order to improve its performance. Tests on the Uni-Flow filter indicate that effluents from this piece of equipment can sometimes be expected to reach about 1500 mg/l of suspended solids. This is true especially if a hose breakage occurs, or immediately after a backflush or hose draining cycle when the hose is relatively clean and a coating of sediment has not built up.

Inclined tube settlers are generally used to clarify wastewater influents which have under 1500 mg/l of suspended solids. Typical flow rates through the settlers are on the



12 banks of hoses @ 64 hoses/bank = 768 hoses

FIGURE 6. Plan View of Uni-Flow Filter for Conceptual System

SCALE: 1" = 5'

order of 3 to 5 gpm/ft^2 and can remove particles down to the 6 micron or smaller range when coagulation is employed. An 8 ft x 38 ft settler would provide 304 sq ft of area and would thus have a flow rate on the order of 4 gpm/ft^2 at 1200 gpm. Such a unit would fit on a standard semitrailer bed.

Auxiliary Equipment

The conceptual removal and separation system will require a total of five semitrailers for transport of the complete 1500 gpm system, including auxiliary equipment. Breakdown of the transportation requirements is as follows:

(1)	Removal System -	1 custom semitrailer to hold MUD CAT dredge and pipe
(2)	Initial Separation -	1 portable scalping-classifying tank and spiral classifiers, size of one semitrailer
(3)	Secondary Separation -	1 Uni-Flow filter on low boy trailer
(4)	Final Separation -	1 inclined tube settler on standard size semi-trailer
(5)	Auxiliary Equipment -	2 pumps, piping, coagulant feeder, etc. to fit on one semitrailer

COST

Table 10 contains the estimated initial cost of the portable separation system which can handle an initial inflow of 1500 gpm. Figure 7 shows approximate portable scalper and

Table 10. ESTIMATED INITIAL COST OF 1500 GPM PORTABLE SEPARATION SYSTEM

Quantity	Item	Cost
1	Portable scalping-classifying tank combined with spiral classifiers (Figure 7)	$84,000
1	Uni-Flow filter: 768, 5" diameter, woven polypropylene hoses with wire cages on the inside and outside	20,000
1	Inclined tube settler: 304 sq ft @ $25/sq ft	7,600
	Auxiliary Equipment: coagulant feeder, piping, 2 pumps	2,100
1	Low boy trailer	12,000
2	Semitrailers	24,000
	Total cost	$149,700

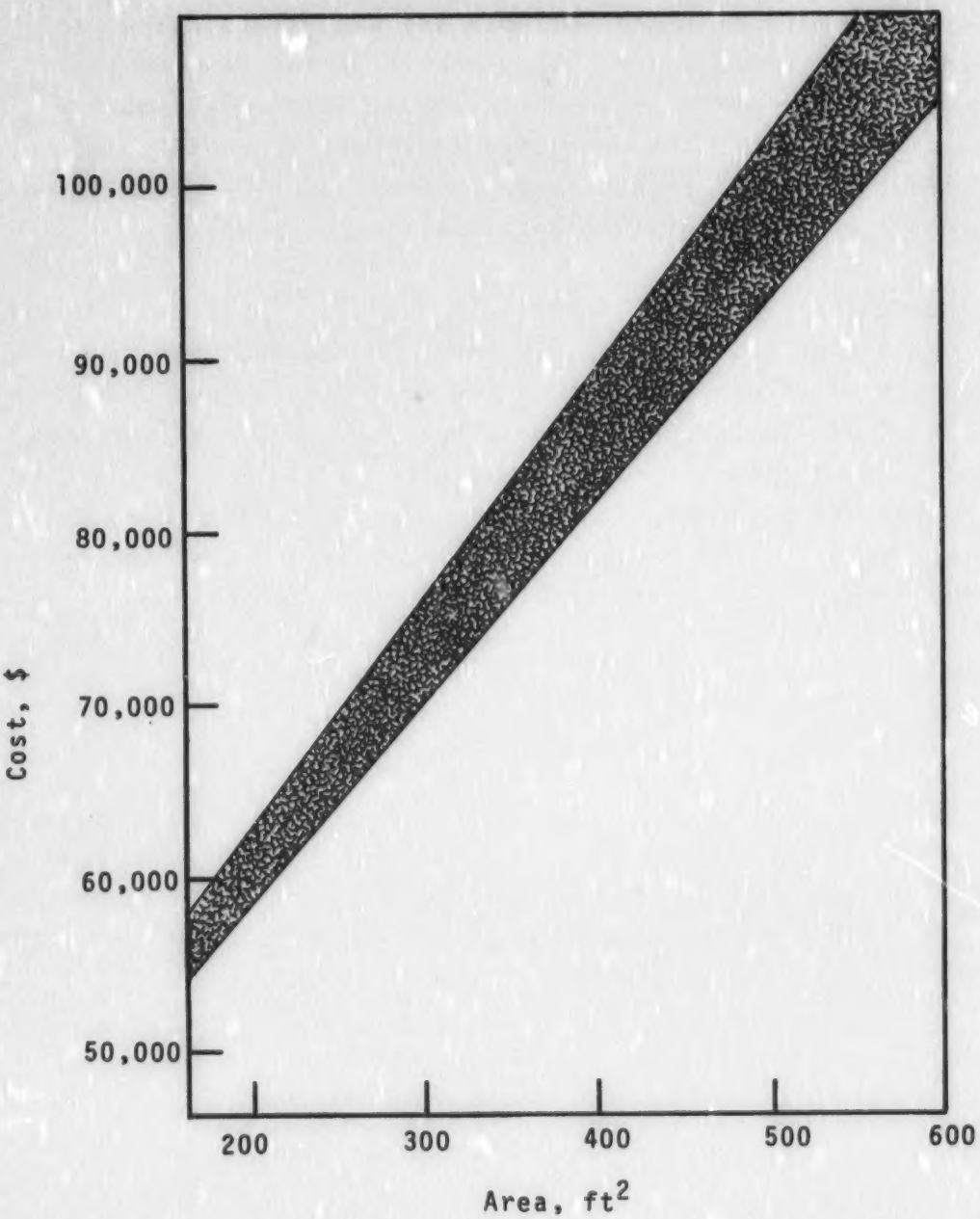


FIGURE 7. Portable Scalper and Classifier Costs (Reference 4)

clarifier costs. The major initial cost of the separation system arises from the portable scalping-classifying tank and spiral classifiers. In order to defray some of these costs, these units are sometimes available on a rental basis. However, the decreased costs during rental must be offset by the decreased responsiveness of the system if no rental units are available at the time of need.

The second major cost item is that of the trailers to transport the processing system. Table 10 reflects the approximate cost of new trailers. Used trailers in good condition can usually be purchased for about one quarter of the cost of a new trailer. Trailers can also be hired on an as needed basis, but again the decreased costs during rental must be offset by the decreased responsiveness of the system if no trailers are available at the time of need.

SECTION VIII

REFERENCES

1. Nawrocki, Michael A., Demonstration of the Separation and Disposal of Concentrated Sediments, U.S. Environmental Protection Agency, Document No. EPA 660/2-74-072, June 1974, 77 pp.

2. American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 13th Edition, Washington, D.C., 1971.

3. Eagle Iron Works, Eagle Water Scalping-Classifying Tanks, Dialsplit ® and Autospec ® Controls, General Catalog Section "B", Des Moines, Iowa, August 1971, 24 pp.

4. Mallory, Charles W., and M.A. Nawrocki, Containment Area Facility Concepts for Dredged Material Separation, Drying, and Rehandling, U.S. Army Engineer Waterways Experiment Station, Contract Report D-74-6, October 1974, 236 pp.

APPENDIX A

ILLUSTRATIONS OF REMOVAL AND PROCESSING EQUIPMENT

FIGURE A-1. Overall View of the MUD CAT Dredge

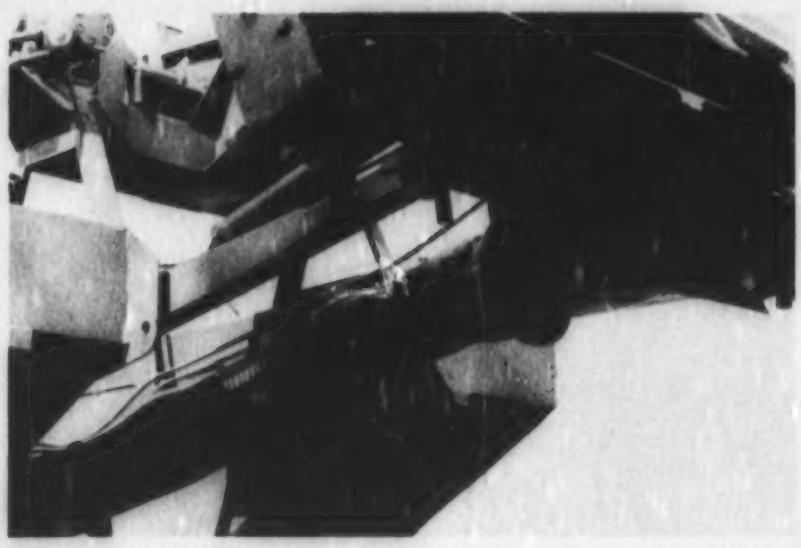


FIGURE A-2. Close-up View of the MUD CAT Auger

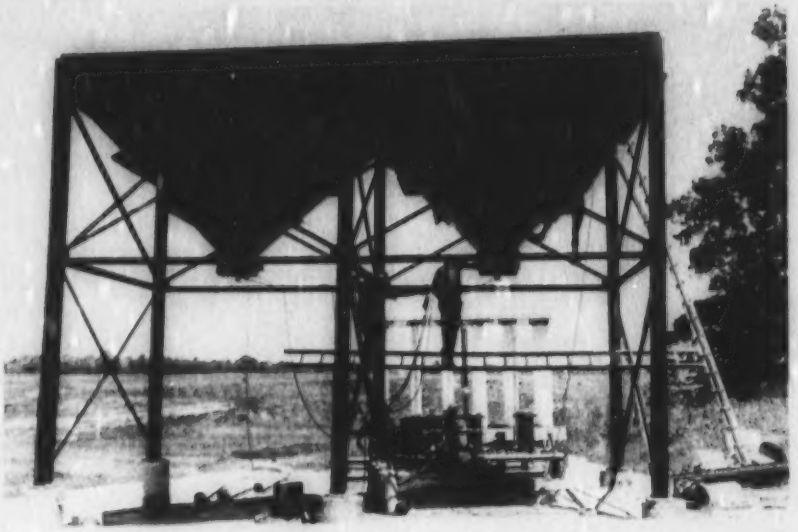


FIGURE A-3. The Two Elevated Bins

FIGURE A-4. Hydrocyclone Unit

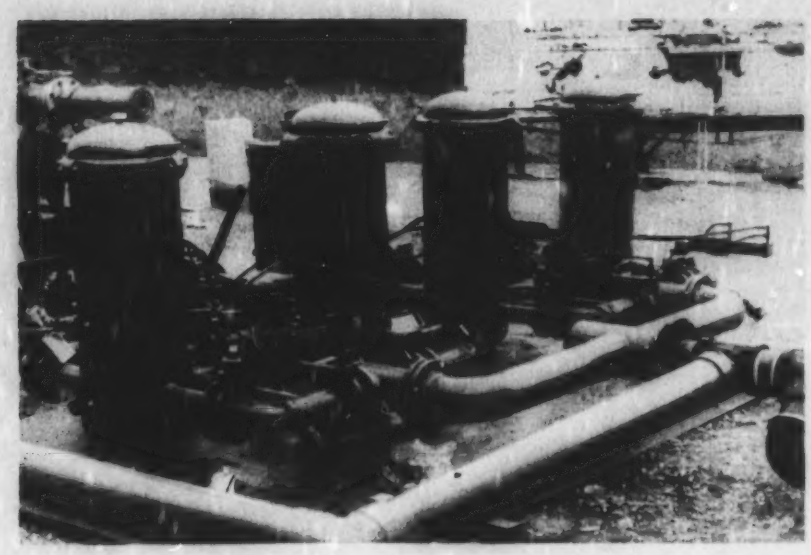


FIGURE A-5. Cartridge Filter Unit

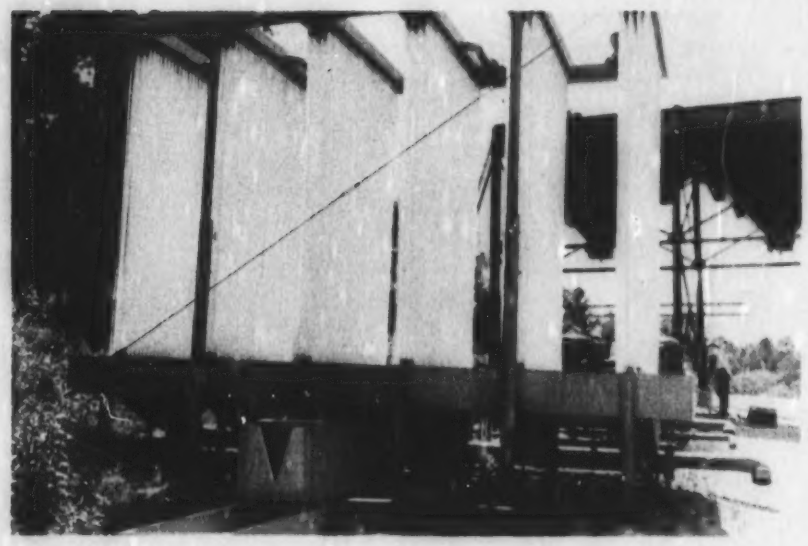


FIGURE A-6. Uni-Flow Filter

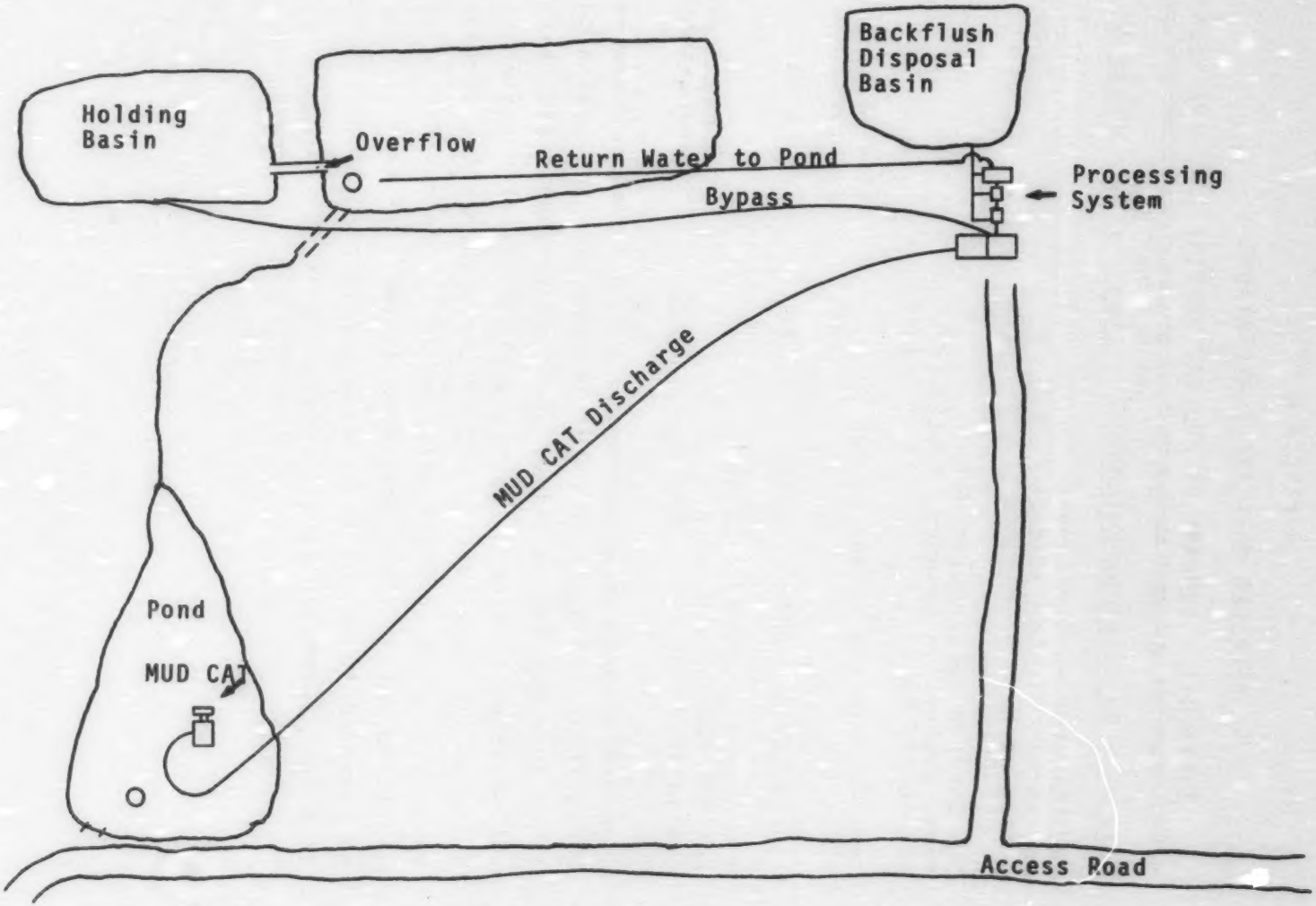


FIGURE A-7. Layout of Demonstration Site (not to scale)

APPENDIX B

DETAILED DATA AND COMPUTATIONS

Table B-1. SUMMARY OF MUD CAT PUMPING RATE ANALYSES

Flow Rate Calculation Method	Flow Rate (gpm)	Remarks
MUD CAT pump rating curves and total friction head in piping as set up in field	2000	- - - -
Sharp-edged rectangular weir formula-overflow between first and second bin	1740	- - - -
Time to fill the volume of the first bin	1660	Time measurement is approximate.
Pipe discharge exit formula	1800	- - - -
Time to fill volume or pipe between MUD CAT and discharge to first bin	1920	Time measurement is approximate.
Average	1820	- - - -

NOTE: The first two flow rates are probably the most accurate since they are the result of exact measurements and fairly well-defined formulae. However, since no valid reason could be found for invalidating any of the results, the average pumping rate of 1820 gpm was used in all calculations. It should be noted, also, that this estimate of flow can only be expected to be, at best, within $\pm$ 10 percent of the actual flow due to the inherent inaccuracies in the formulae.

TABLE B-2. VALUES FOR CALCULATING AMOUNT OF SIMULATED HAZARDOUS MATERIAL IN BINS

Test Material	Bin	Depth of Sediment (ft)	Volume of Sediment			Weight of Test Material (lb)	Specific Gravity of Bin Residue
			From Lead-in Area (ft^3)	From Entire Dredging (ft^3)	From Test Area (ft^3)		
Iron Powder	#1	4.5	6.68	71.26	64.58	210.36	2.70
	#2	2.5	1.14	12.18	11.04	12.49	2.61
Glass Beads	#1	3.5	11.85	33.10	21.25	0.34	2.59
	#2	1.5	1.18	3.31	2.13	0.05	2.61
Iron Filings	#1	3.5	5.89	33.10	27.21	*	*
	#2	1.5	0.59	3.31	2.72	*	2.51
Coal	#1	3.5	7.60	33.10	25.50	447.27	2.51
	#2	1.5	0.76	3.31	2.55	3.99	2.51

* Sample believed to be nonrepresentative.

Table B-3. TOTAL SIMULATED HAZARDOUS MATERIALS BALANCE

Unit	Test Material (Total lb removed) Glass Beads	Iron Filings	Iron Powder*	Coal*
Elevated bins	113.4	526.4	130.2**	97.0**
Bypass	339.4	40.6	84.6**	42.2**
Hydrocyclones	17.3	6.7	2.1	3.7
Cartridge Filters	1.2	0.6	1.1	2.0
Uni-Flow	1.2	0.7	1.7	1.0
Subtotal:	472.5	575.0	219.7	145.9
Pounds in outfall (return water to pond)	<0.1	<0.1	<0.1	<0.1
Pounds left on bottom	<0.1	0.4	8.0	2.1
Total weight accounted for	472.5	575.4	227.7	148.0
Total weight placed on bottom	500.0	500.0	800.0	500.0
Percent material accounted for	94.5	115.1	28.5	29.6

* Because of inaccuracies in measuring the amount of iron powder and coal in the bypass, and the fact that these two simulated hazardous materials were nonuniformly distributed in the bin sediments, the values shown for the pounds removed by the elevated bins and the bypass may not reflect the true values.

** Imputed value.

Table B-4. SUMMARY OF EFFLUENT CONCENTRATIONS
(mg/l)

Component	Average	Maximum*	Minimum
MUD CAT Discharge	128,460	160,500	107,030
Elevated Bins	82,520	140,500	55,830
Demco	53,800	103,040	31,400
Crail	40,860	94,430	22,740
Uni-Flow (Return Water to Pond)	750	1,770	230

* All of the maximum values come from one test, the test for removal of paint.

Table B-5. BACKFLUSH CONCENTRATIONS

Component	Suspended Solids (mg/l)		
	AVG.	MIN.	MAX.
Demco	56,060	8,570	106,250
Crall	103,660	37,680	284,580
Uni-Flow	84,640	25,900	191,600

NOTE: The various units were manually backflushed at the end of the test period. If left to backflush in the automatic mode, the concentrations of suspended solids in the backflush would have been different. Normally, the various units were set to backflush on a regular basis which usually corresponded to the time the backpressure in the unit built-up to near a maximum permissible level. Thus, the backflush concentration values in these tests do not necessarily reflect the maximum increase in the solids concentration in the backflush as compared to the concentration in the influent which can be achieved by the unit. On a continuous operation basis the advantage of this system would be in being able to isolate and subsequently dispose of most of the hazardous material in the backflushes of the various units in concentrated form.

Table B-6. PERCENTAGES OF SIMULATED HAZARDOUS MATERIAL (S.H.M.) IN THE EFFLUENTS OF THE PROCESSING SYSTEM ELEMENTS

Sampling Point		Test Material			
		Iron Powder	Glass Beads	Iron Filings	Coal
Percent S.H.M. in Effluent	#5	3.70	4.87	11.80	2.30
	#1	3.30	4.59	1.63	2.00
	#2	2.90	1.60	0.41	1.00
	#3	2.70	1.10	0.37	0.50
	#4	0.05	0.08	0.05	0.05
Percent S.H.M. in Residue	Bin 1	2.0	0.010	75.8	11.2
	Bin 2	0.7	0.014	21.8	1.0

Sampling Point Key

#5 = MUD CAT discharge into elevated bins

#1 = Bin effluent - Influent to Demco Centrifugal Separator unit (hydrocyclones)

#2 = Demco effluent - Influent to Crall cartridge filters

#3 = Crall effluent - Influent to Uni-Flow bag-type filter

#4 = Uni-Flow effluent (return water to pond)

EXAMPLE CALCULATION

To compute the amount of simulated hazardous material (S.H.M.) in the influent to the hydrolocyclones (effluent from the bins) for the Iron Powder test, the following data are used:

(1) Sampling Point	(2) Dredged Slurry Concen. (mg/l) (from Table 5)	(3) %S.H.M. in Effluent Solids (from Table B-6)	(4) S.H.M. Concen. (mg/l) (Col.3 x Col.2)	(5) Soil Concen. (mg/l) (Col.2 - Col.4)
#1	61,320	3.30	2024	59,296

Assume mg/l = ppm.

The total pounds of S.H.M. passing the sampling point during the entire test can then be computed by:

Total lb =[flow (gpm)] x [wt. of water (lb/gal) x specific gravity of slurry] x [S.H.M. concentration] x [duration of test (min)]

Therefore, Total lb = [100 gpm] x [8.35 lb/gal x 1.04] x [.002024] x [2.8] = 4.[illegible] lb

APPENDIX C

ALTERNATIVE EQUIPMENT

The following section contains brief descriptions of additional alternative pieces of equipment that were investigated for their possible use in the conceptual portable processing system but were not included in the final system.

(1) ELECTRO/MEDIA, Hi-Velocity, and Plastic Media Filters, Hayward Filter Company, Santa Ana, California. Filters produced by this company are normally used for water clarification and wastewater treatment. They filter water by passing it through various media such as sand, garnet, coal, plastic, and aluminum-bearing granules. Turbidity removals of 95 to 99 percent have been reported for these filters. Their drawbacks for portable service include their large size (requiring over four times the space of the Crall filters) and high weight. Flow rates for the three Hayward filters range from 15 to 30 gpm per square foot of filter area.

(2) Rotostrainer®, Hydrocyclonic Corporation, Lake Bluff, Illinois. The Rotostrainer® system of solids dewatering has advantages over other screening methods. The size, 2(29" x 72"), takes between 1/2 to 1/3 the space as other methods. Also, it is self-cleaning with the dewatering solids from raw sewage producing a dry weight of 25%. The cost for a 1500 gpm unit is approximately $10,000, with maintenance costs relatively low. One major drawback with the Rotostrainer® is the 250-micron final particle retention size at the required flow rate which is well above the needed requirements.

(3) Adams PORO-EDGE Automatic Water Strainers, R.P. Adams Company, Inc., Buffalo, New York. These filters are used in general service for water clarification and process water treatment. Again, their main use is in permanent installations. The standard unit comes

equipped with openings to strain particles in the 250-micron or larger range, although finer and larger opening sizes are available. The PORO-EDGE Automatic Water Strainer might be a good piece of equipment for use in the initial solids removal step of the full capacity 1500 gpm system if the absence of large rocks could be guaranteed. The cost of such a strainer would be on the order or $2500.

(4) Matz Micro-Solids Separator, Matz Corporation, Holyoke, Massachusetts. This is a relatively new piece of commercially available equipment. Limited data are available on its performance characteristics. However, some tests show suspended solids removal rates on the order of 83 percent for initial concentrations in the 130 ppm range. The equipment backwash cycle requires a greater number of moving parts than other water clarifiers, thus leading to a possible increase in maintenance and downtime, important considerations in field installations.

(5) Flat Bed Pressure Filter and Hydro-Vac Filter, Hydromation Engineering Company, Livonia, Michigan. These filters are used primarily in industrial filtration of waste streams from metal working operations and washing systems, and chemical process liquors. These fabric filters are used exclusively in permanent installations. Their rated filtration removal of particles down to one micron in size is excellent although their large size (requiring approximately 200 square feet of area for only a 500 gpm unit) and bulky shape make them unwieldy for portable field use. Cost of a 500 gpm unit (approximately $38,000) is also high compared to other available equipment.

(6) Akin to the above Hydro-Vac and Flat Bed Pressure Filters are a number of standard rotary drum or moving belt filters. These filters utilize fabric to screen the inlet process water. Very fine filtration can be achieved by using precoat materials on the fabric or by utilizing new types of fabric being developed. Flow rates on the order of 1 to 10 gpm per square foot of filter area are commonly achieved. The cost of a 500 gpm unit would be on the order of $30,000 to $40,000. The equipment is bulky and not suited for portable field application. Manufacturers of such filters include Dorr-Oliver of Stanford, Connecticut; Impco of Nashua, New Hampshire; Komline-Sanderson of Wilmington, Delaware; and Eimco of Salt Lake City, Utah.

(7) Continuous Solid Bowl Centrifugal, Bird Machine Company, South Walpole, Massachusetts. Centrifuges of this type employ a rotating drum to concentrate the solids from a solids-liquid mixture. Small units of this type would lend themselves to easy portability. For example, a solid bowl centrifugal which could handle a flow rate of 300 gpm would only occupy a 3 foot by 12 foot space and could be readily mounted on a trailer. Rejected solids from these units can be expected to be approximately 20 to 45 percent solids by weight. The cost of these units, however, makes them a less attractive alternative. Selling price for a 300 gpm unit, less auxiliaries, would be approximately $75,000. In addition, the machine would require a 200 horsepower drive motor, either electrical or diesel.

(8) Dewatering screens. These are basically screens of a specific mesh size set at an angle. A slurry flows

over the surface, with water flowing through the screen with the solids being collected at the lower end of the screen. These units are used in the pulp and paper industry, for fruit and vegetable processing, in sand and gravel processing, and in the mining of iron and copper ore. They have flow rates of between 30 to 500 gpm per screen, depending upon mesh size of the screens. Mesh sizes range from 2.38 mm to 44 microns. They are made for permanent installation, but because of their size they could be used for portable applications.

(9) Vibrating screens. These screens are similar to normal dewatering screens except for the fact that they are vibrated during processing. They are normally used in sand and gravel processing to remove particles greater than about one-tenth of an inch in diameter. Small size screens, down to 400 mesh, can be used, but the flow rate drops considerably. Thus, more screens would be required for a high flow rate. Manufacturers of vibrating screens include: Smith Engineering Works, Wisconsin; Denver Equipment Division of Joy Manufacturing Co., Colorado; Kribs Engineers, California, Derrick Manufacturing Corp., New York; and SWECO, Inc., California.